

Distinguishing Between Supra-Arcade Downflows and Plasmoids



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Abstract: Supra-arcade downflows (SADs) and downflowing loops (SADLs), observed as sunward-traveling voids and thin flux tubes in the current sheet region above developing flare arcades, are considered indicators of magnetic reconnection fueling long-duration solar eruptions. These flows are located in regions of very low signal-to-noise in the corona where high cadence magnetic field measurements are not yet achievable, making observations difficult to fully interpret with respect to reconnection. Several models have been developed to explain their characteristics and behaviors, but most do not successfully recreate the observations. We will present a variety of downflow observations and provide comparisons to a number of the more prominent models.

Supra-Arcade Downflows (SADs) Observations

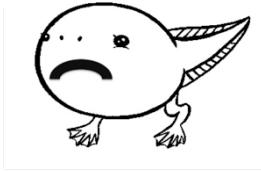


Fig 1

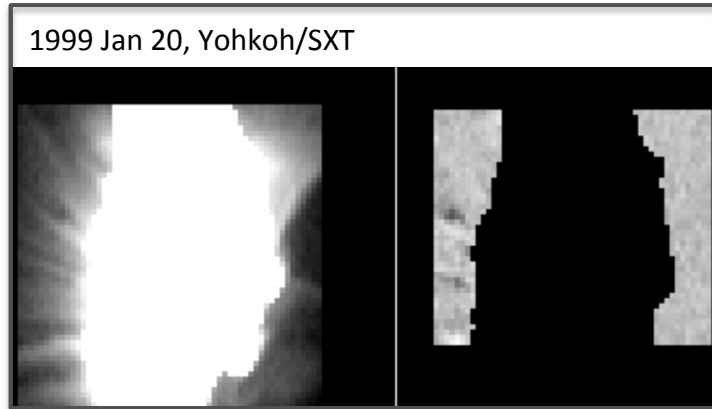


Fig 2

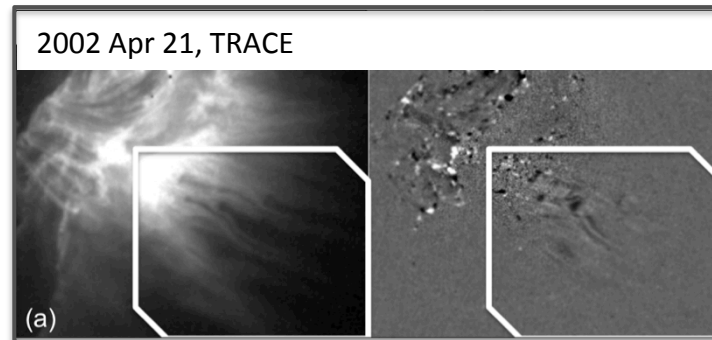


Fig 3

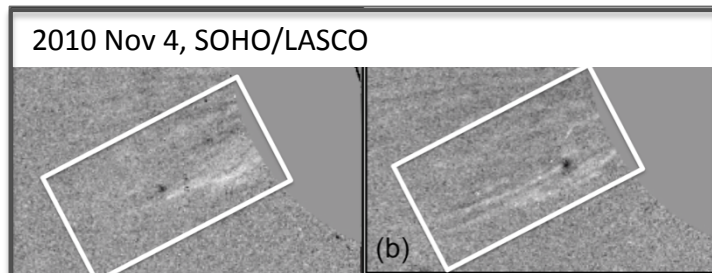
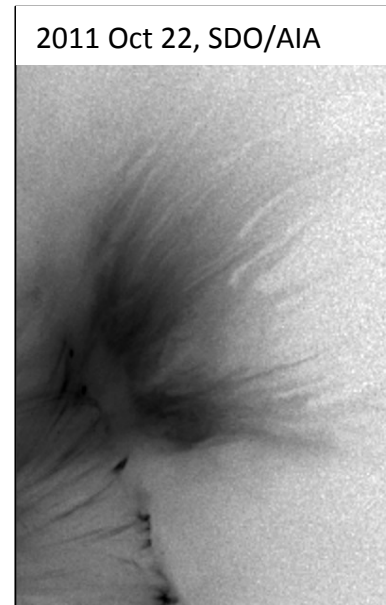
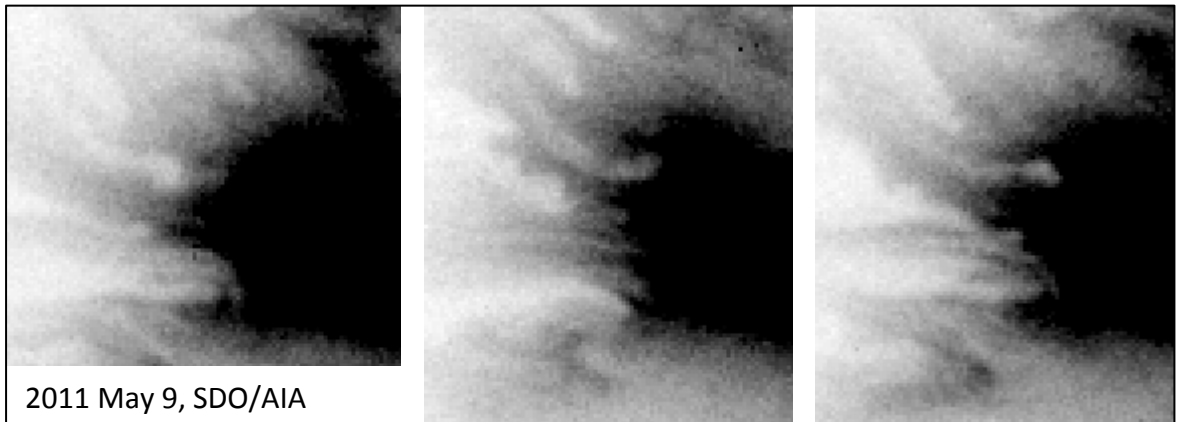


Fig 4



- Teardrop-shaped **voids** observed to travel sunward through the bright, hot fan extending outward along the spine of developing post-flare arcades.
- Observed with high-temperature instrumentation (EUV, X-ray) & white-light coronagraph (density)

Fig 5



Plasmoid Observations

- Coherent 'bubble' of **emitting** plasma held together by magnetic fields.
- Observed with broadband-temperature instrumentation (EUV, X-ray, Hard X-ray) & white-light coronagraph (density)

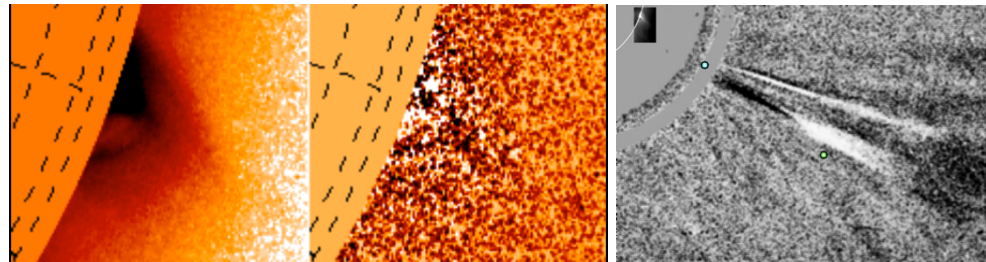


Fig 1

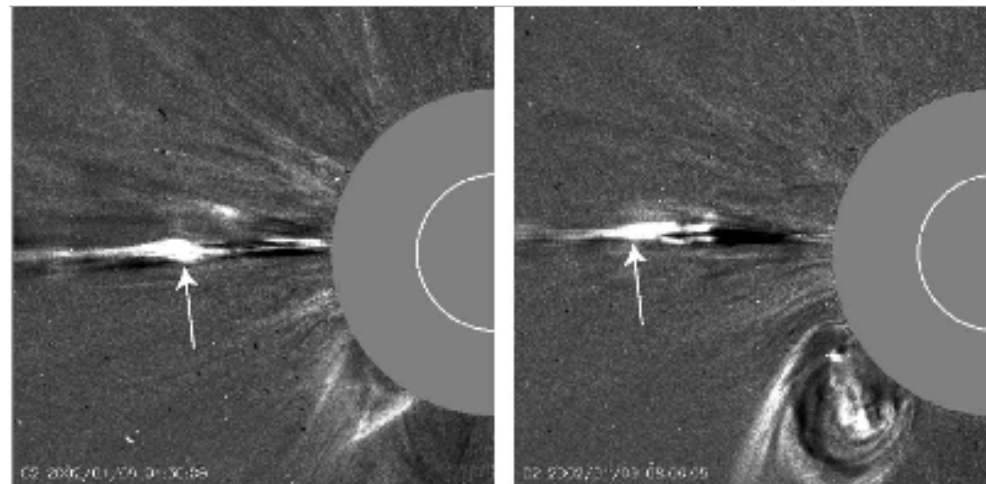


Fig 2

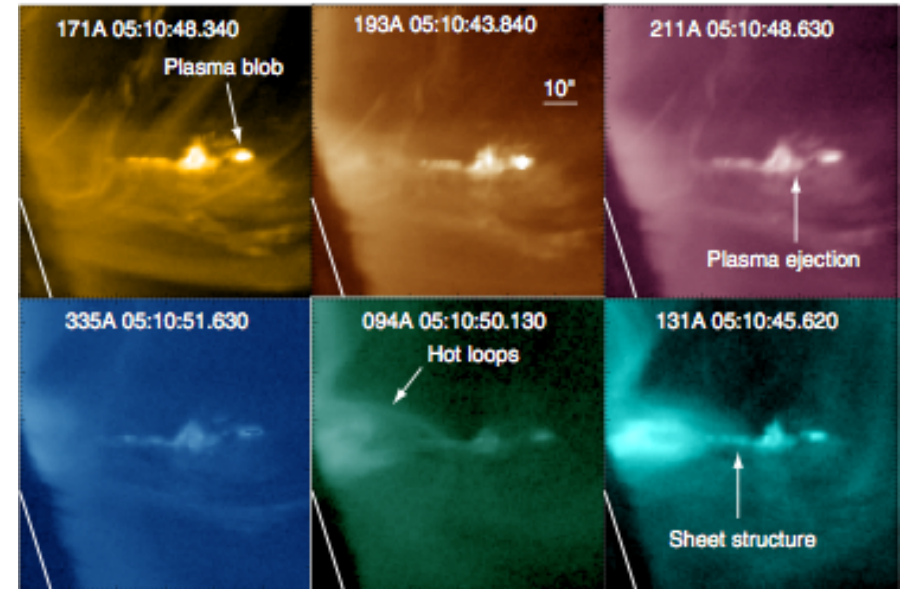


Fig 3

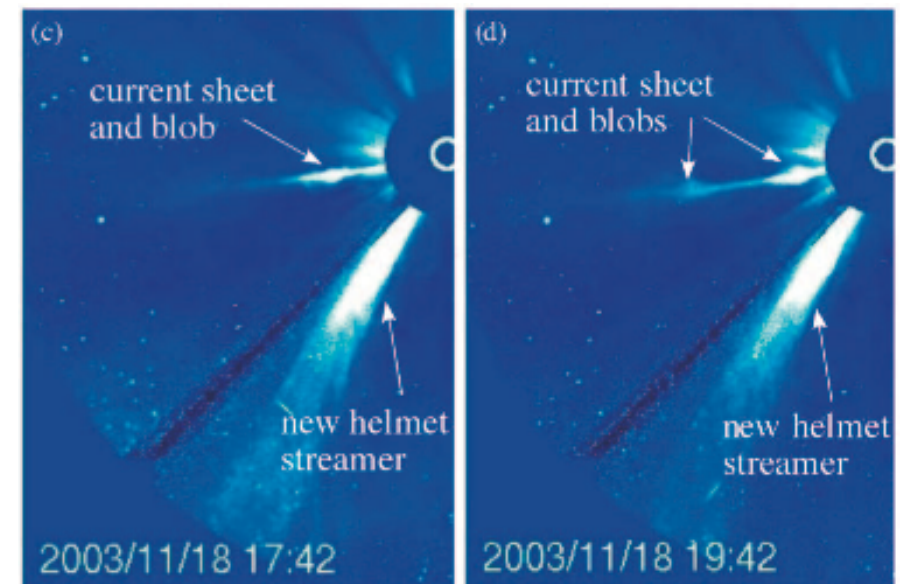


Fig 4

Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1

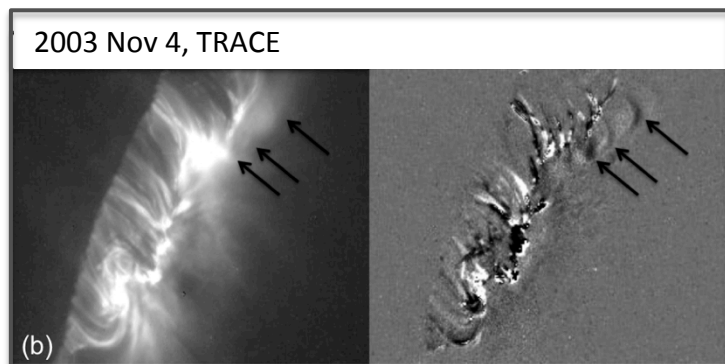


Fig 2

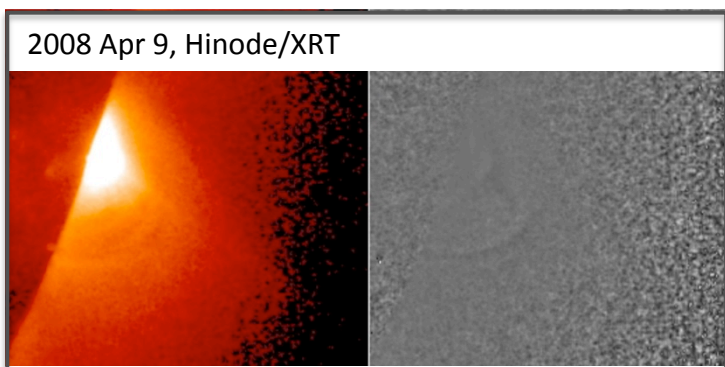


Fig 3



2010 Nov 3, SDO/AIA

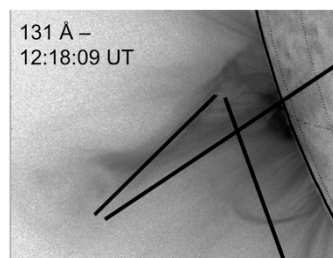


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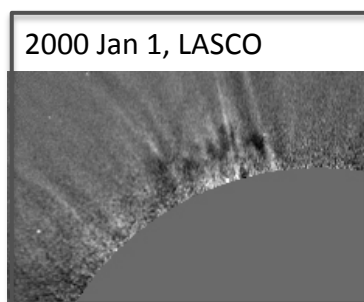
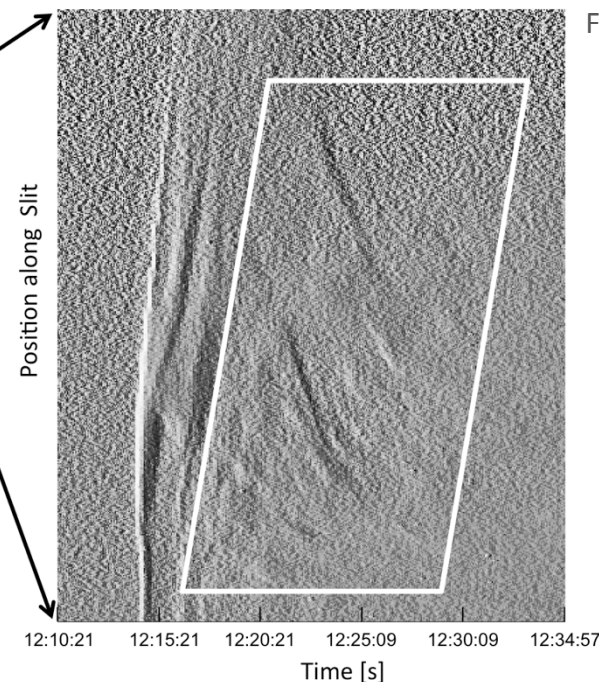


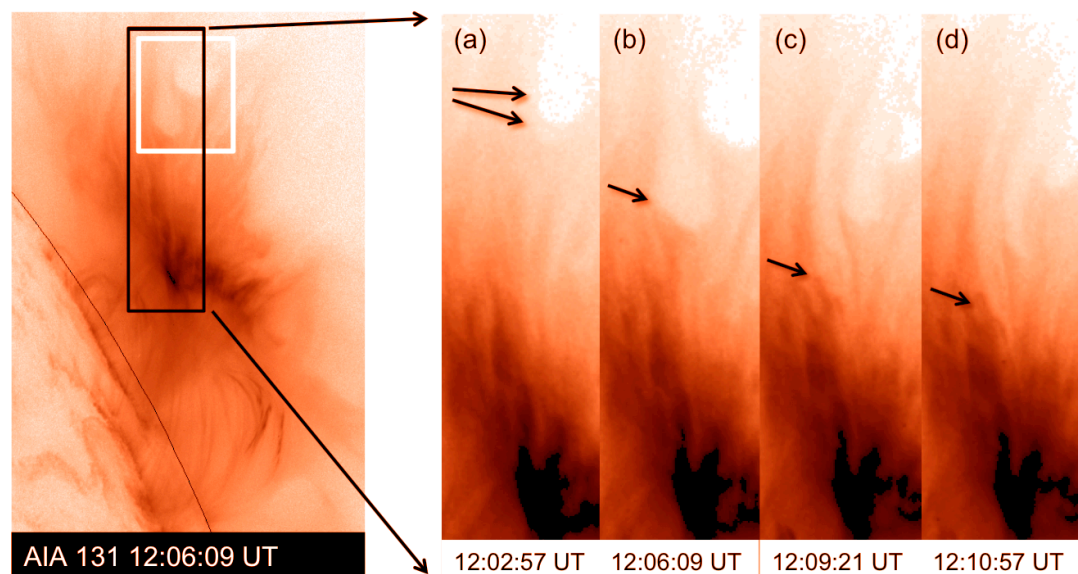
Fig 4



- Shrinking loops observed to travel sunward **across** the bright, hot fan extending outward along the spine of developing post-flare arcades.
- Observed with high-temperature instrumentation (EUV, X-ray) & white-light coronagraph (density)

SADs + SADLs

Fig 1



- SADs appear to be voids created by loops (SADLs) shrinking through the fan plasma.

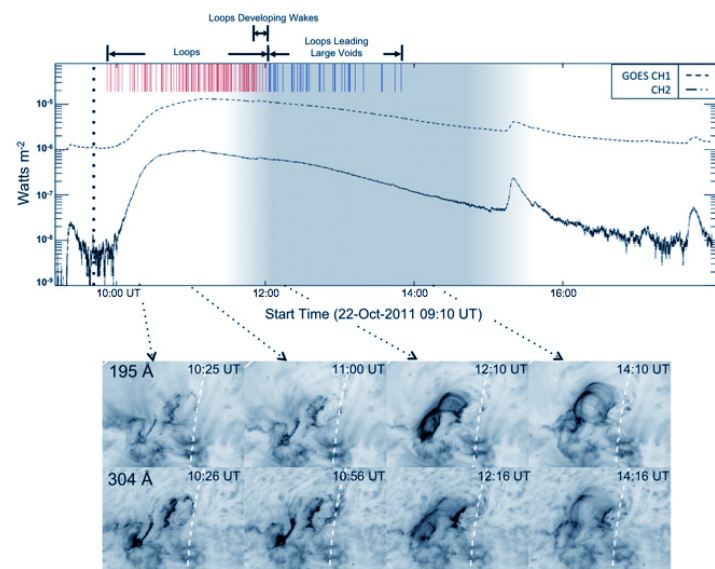


Fig 2

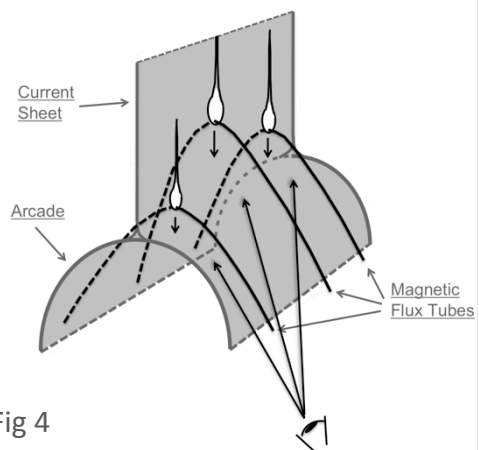


Fig 4

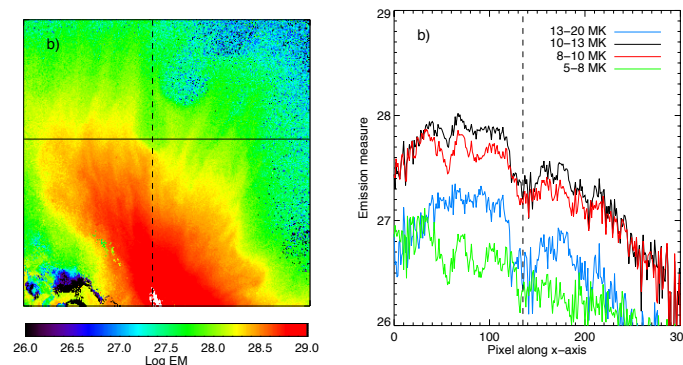


Fig 3

Example Models & Simulations

Fig 1

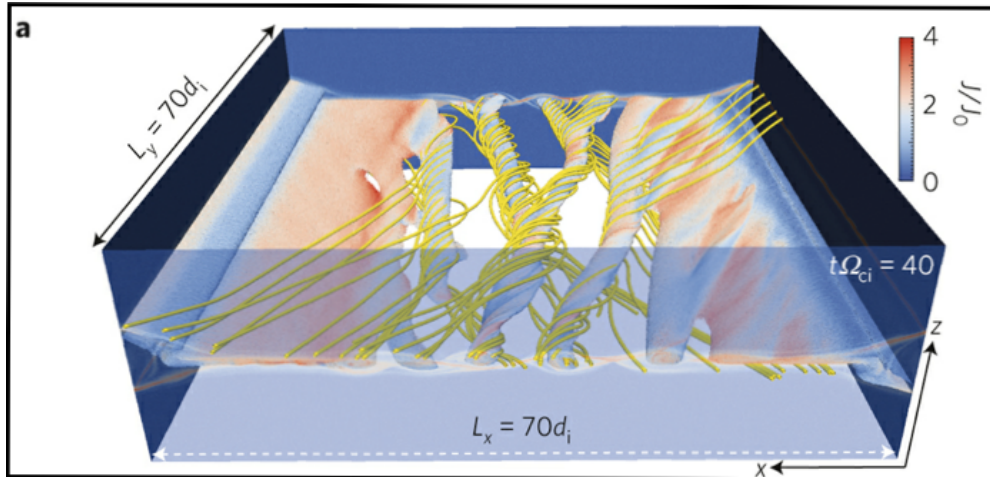
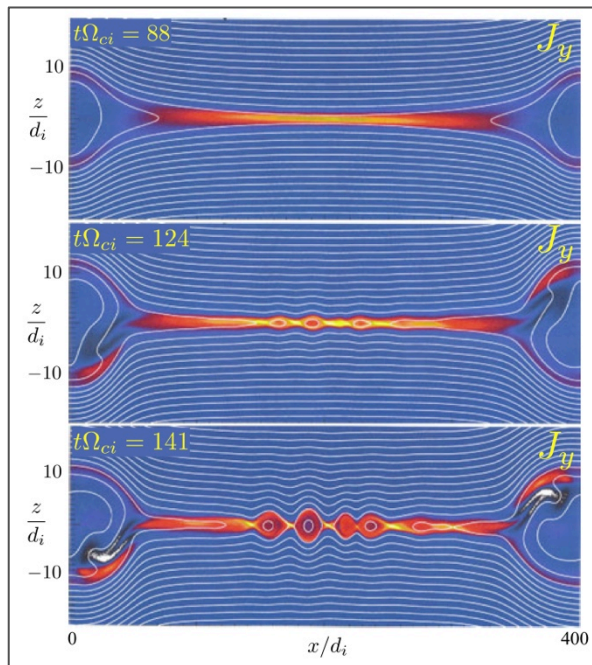


Fig 2



- Thin flux tubes created during the reconnection process across the current sheet.
- Plasmoids a 3-D product of reconnection concurrent to single loop creation.

Fig 3

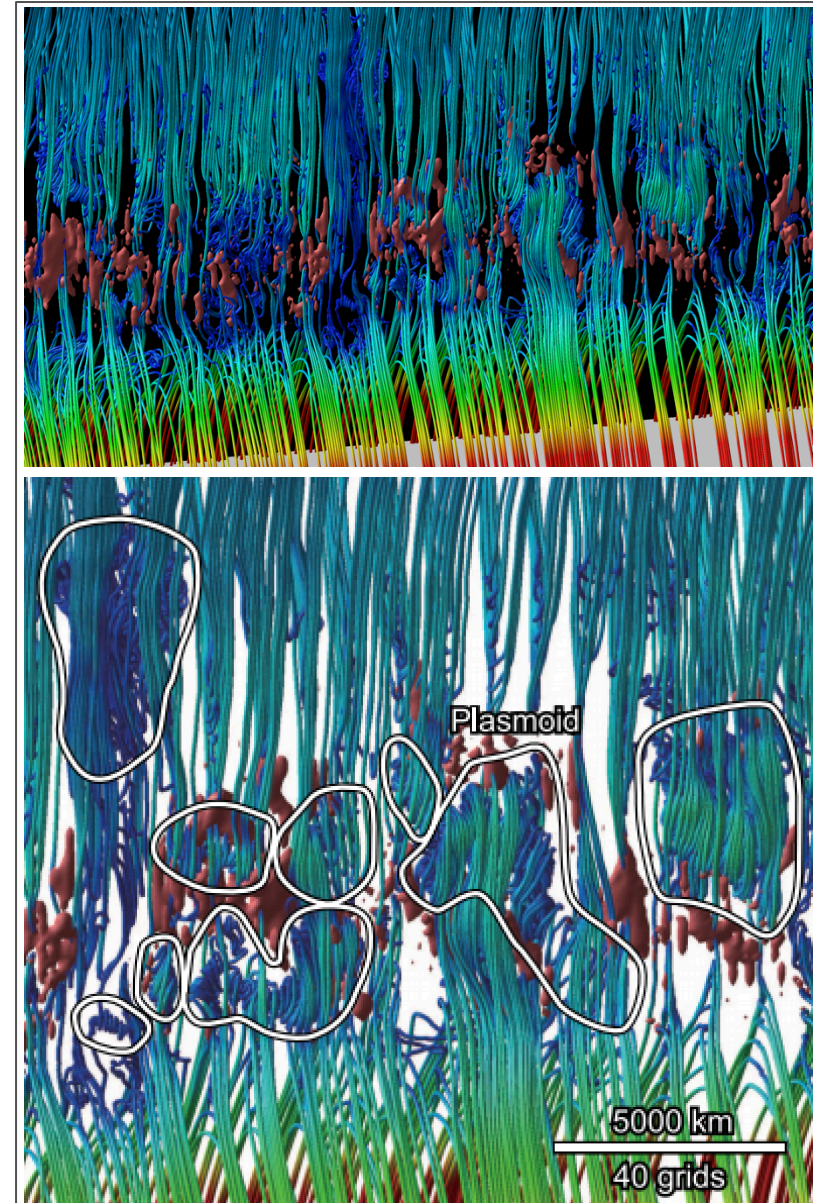


Diagram Models

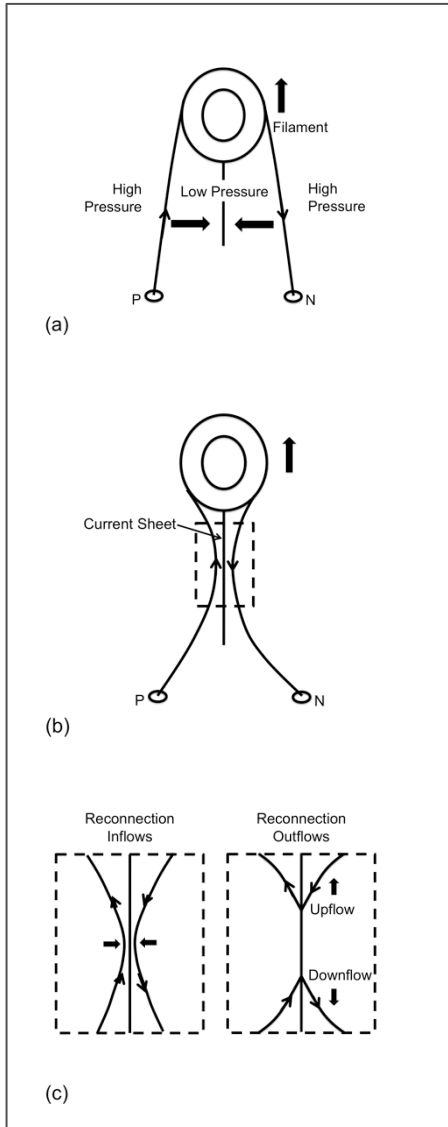


Fig 1

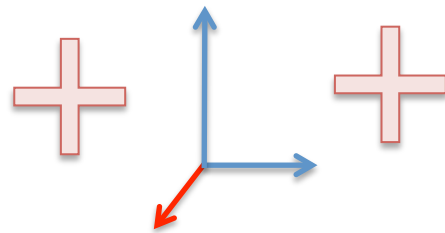


Fig 2

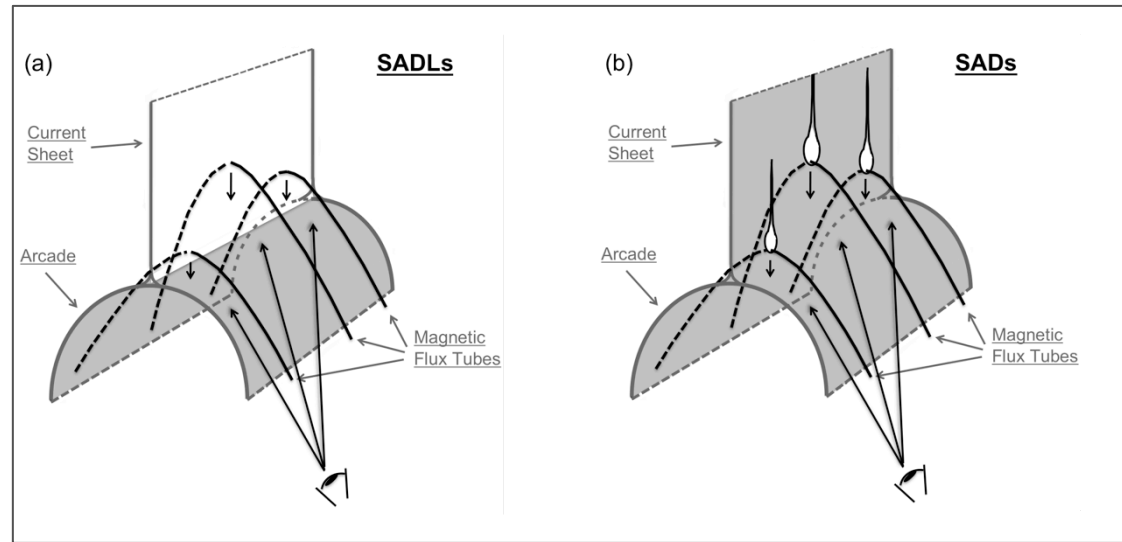


Fig 3

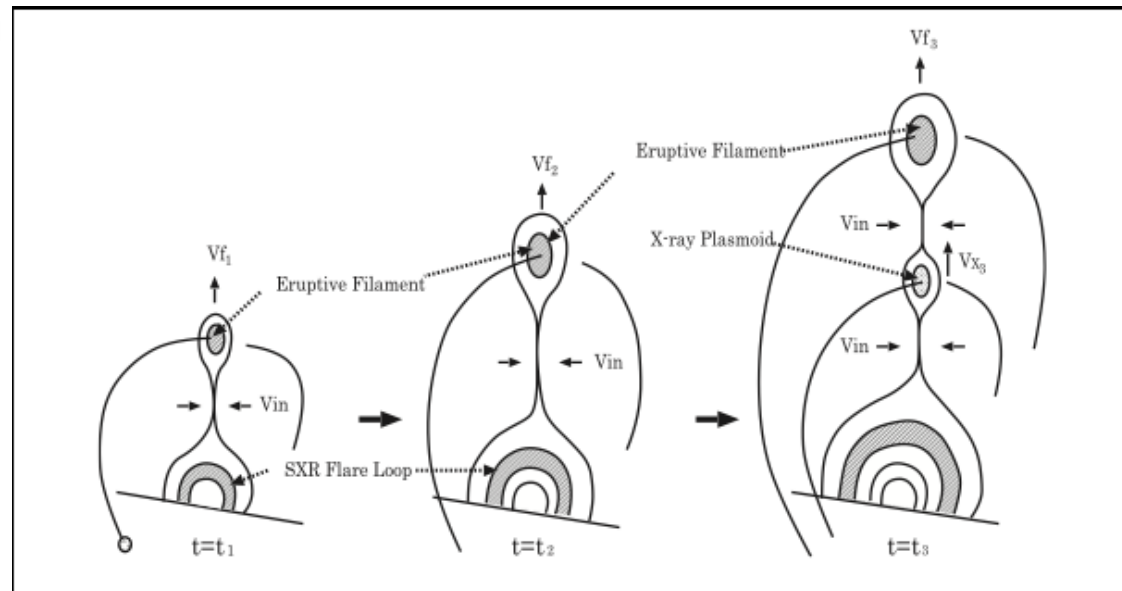
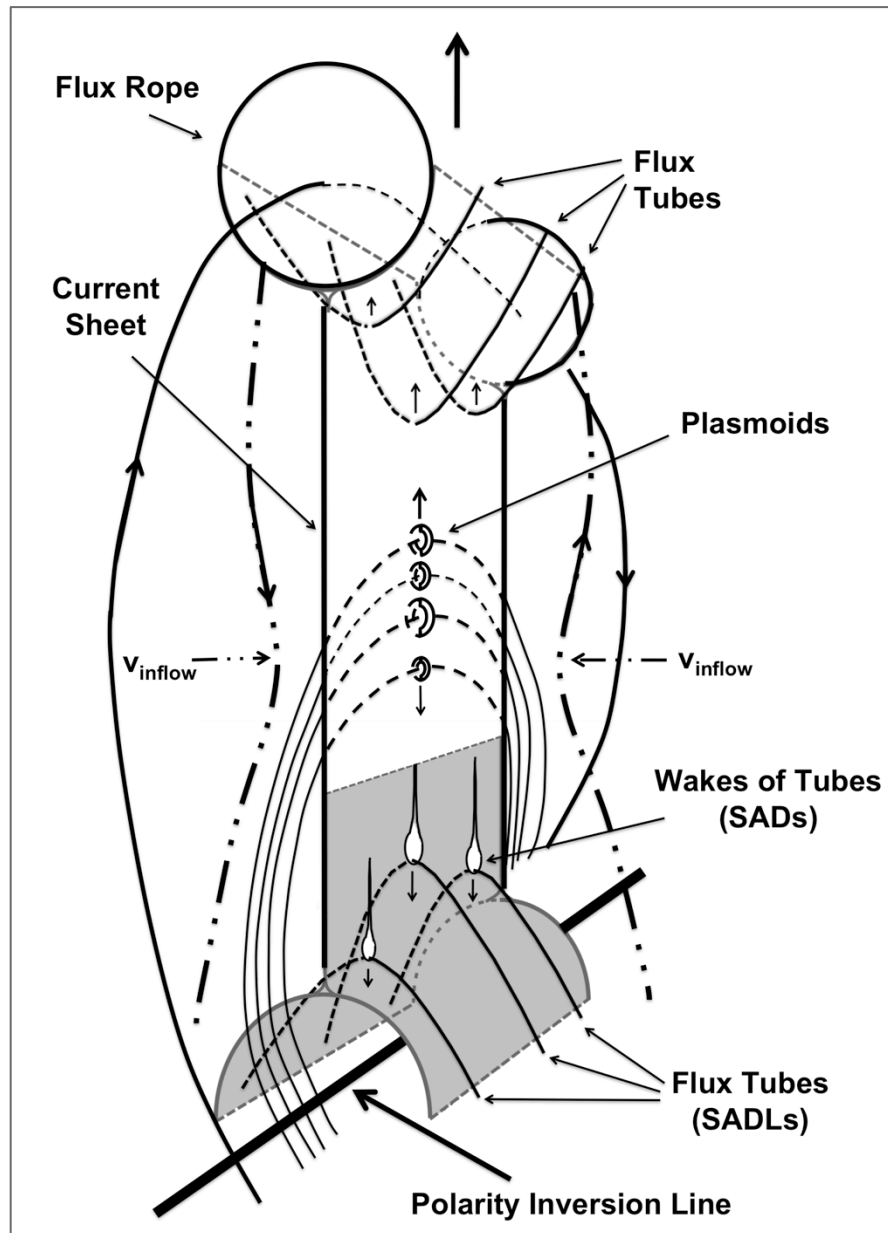


Fig 3: Ohyama & Shibata 2008

Fig 1, 2: Savage et al. 2012

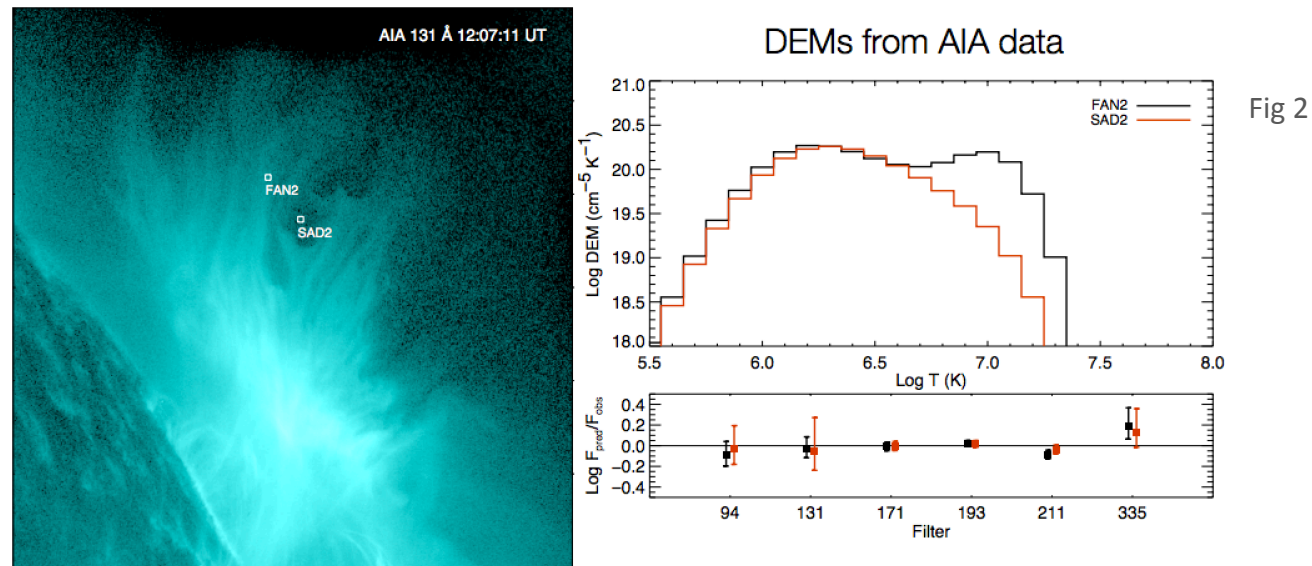
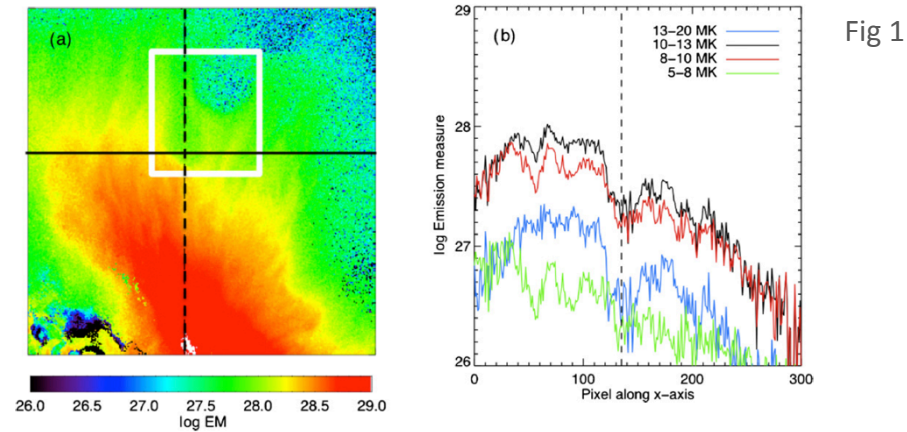
Fig 1



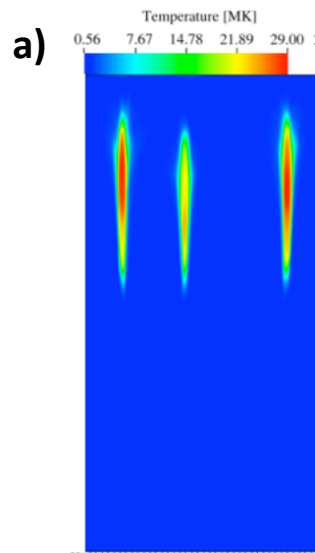
- Basic reconnection scenario, post initial flux rope formation and release.
- General organization of the magnetic field of the various components (SADs, SADLs, plasmoids).
- Field lines reconnect across the current sheet to form outflowing flux tubes while plasmoids form in the current sheet.
- SADs are formed as the flux tubes (SADLs) retract through hot plasma in the fan (*otherwise, only SADLs are observed*).

Model Constraints

OBSERVED TEMPERATURE AND DENSITY ALWAYS LOWER THAN FAN



Models

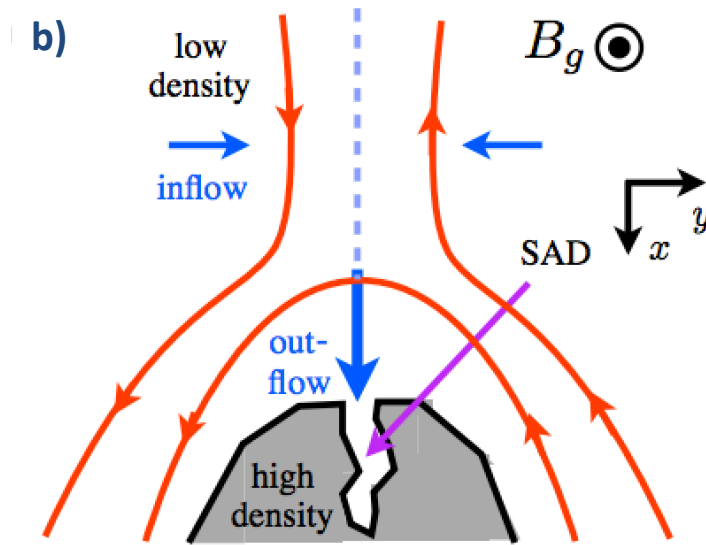


Pressure pulse + MHD wave

($T \gg \text{fan}$)



Too hot with respect to the surroundings

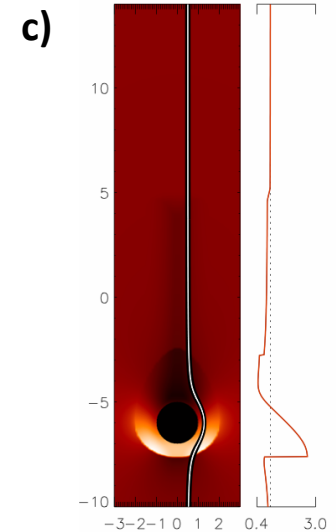


Reconnection outflows

($T \sim < \text{fan}$)



Incorrect geometry with respect to observations



Peristaltic pumping

($T \sim < \text{fan}$)

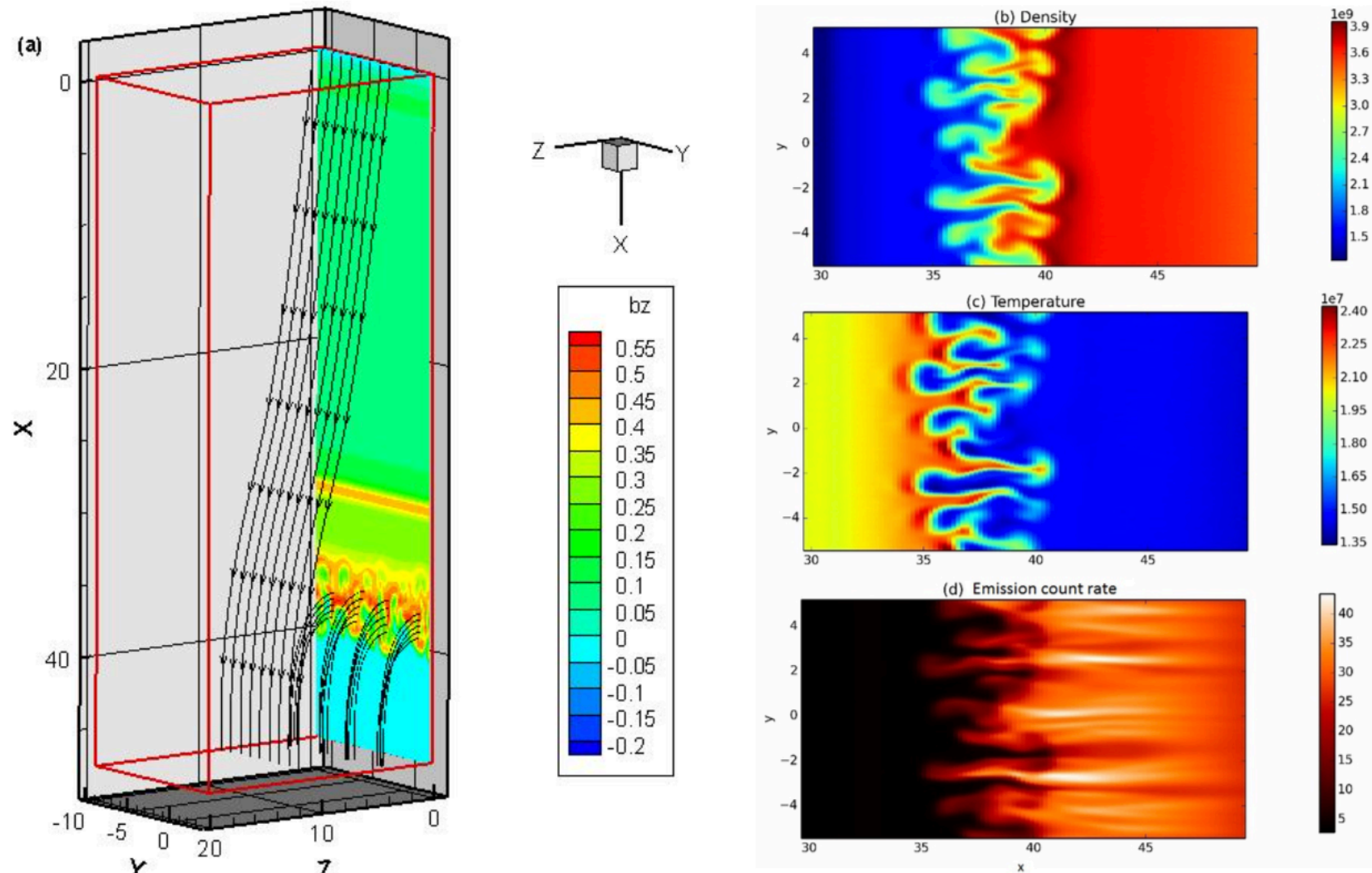
Incomplete, feasible;
Difficult to match to
observations

Fig 1: Cecere et al 2012

Fig 2: Cassak et al 2013

Fig 3: Scott et al 2013

Models, cont.



Rayleigh-Taylor Instabilities behind retracting flux tubes ($T > \text{fan}$)

Too hot with respect to the surroundings

BUT

Best match to observations to date (3D!!!)
although early in development

Sum up

- Plasmoids and SADs consequences of the same general process.
 - i.e., reconnection in the current sheet fan above arcade-forming eruptions
 - *However*, plasmoids and SADs have very **disparate morphologies**.
 - ergo, size, speed, field strength, etc. have different distributions
 - What can be learned through comparison?
 - timing of formation (do plasmoids typically form later in the event, as in the case for XRT flare 2008 Apr 9?)
 - 3-D structure of the current sheet (length scales)
 - Strength of the guide field
 - Do plasmoids create an effective drag on the shrinking loops?
 - Indications of a source for patchy reconnection (turbulence, instabilities)
- Most models do not match the SAD/SADL observations well
 - Best model to date is in development by Guo et al (2013), wherein SADs are the result of Rayleigh Taylor Instabilities behind flux tubes retracting through the fan arcade